This plot of bermuda and fescue grass on a northern Alabama stripmine spoil bank was photographed in 1697 a few months after the application of a combination of compost from the Johnson City plant, fertilizer, water, and seed. Before reclamation, the spoil bank had the same poor appearance as the untreated area in the upper part of the picture. The plot has now survived two growing seasons and the rigors of more than two full years of varying weather.

AMERICAN COMPOSTING CONCEPTS

This publication (SW-2r) was written
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P. H. McGAUHEY

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FOREWORD

THERE IS AN ACCUMULATING body of evidence that composting of municipal refuse provides a tool for solving only a small portion of this Nation's solid waste disposal problems. At present, however, composting is the only solid waste disposal process that salvages the organic fraction and is accordingly deserving of research consideration. In fact, since the Solid Waste Disposal Act of 1965 specifically directed that research be carried out on the recycling and reclamation of waste materials, it would appear that the composting process cannot be ignored by the managers of solid waste systems as long as it remains the only known means of reclaiming organic solid wastes.

When the Federal solid waste program became operative in 1966, composting with sewage sludge was the subject of one of the first research projects undertaken. The cooperation of the Tennessee Valley Authority, the municipality of Johnson City, Tennessee, and the Bureau of Solid Waste Management made possible a demonstration of composting on municipal scale—the joint U.S. Public Health Service-Tennessee Valley Authority Composting Project at Johnson City.

Based on a full year's experience of plant operation, with concomitant research on the health aspects of compost use and processing as well as investigation of the engineering and economic factors, the Bureau felt that it would be able to make an initial evaluation of the composting process as a means of managing municipal solid wastes and sewage sludge by late 1969. As background preparation for completing such a position document, Professor McGauhey, of the University of California and a Public

Health Service consultant with longwhile interest and many years of investigation on the subject, was asked to contribute his present judgment on the value of composting municipal refuse in solid waste management systems.

In his review of the current status of composting and related research in the United States, Professor McGauhey notes that interest in this subject has developed in response to three factors: the increasing population and pollution resulting from disposal of waste products; a growing affluence that has multiplied the per capita quantities of wastes generated; an enlarging critical mass of entrepreneurs, conservationists, and persons interested in specialty agriculture, including organically-grown foods.

Research conducted in the early 1950's, and verified from time to time since then, has defined the operating parameters for composting municipal and other organic refuse as well as the disposal of the final compost. More recently, the role of composting as only one of a number of processes in the optimum regional management of solid wastes has been found important.

Even though composting is by no means a profit-making solution to municipal refuse disposal, as claimed by some of its more enthusiastic adherents, reliable information on process costs is needed. Such information has been obtained through the Bureau of Solid Waste Management research efforts. With respect to the value of compost as a resource, Professor McGauhey concludes that the conversion of a "low-value waste material that nobody wants" into a "low-value resource that nobody wants" should be deferred; this might be done by placing solid wastes in sanitary landfills until such time that their value warrants their mining and recovery.

—RICHARD D. VAUGHAN
Assistant Surgeon General
Acting Commissioner
Solid Waste Management Office

PREFACE

THE PURPOSE OF THIS PAPER is to review the status of composting as a process for the management of municipal solid wastes and to ascertain what research and development may be appropriate to composting in 1969—when considered against the urgency of other components of the national solid waste problem and the budgetary limitations of the Bureau of Solid Waste Management. The evaluation is based on the author's own judgment and opinions. These are derived from his experience in solid waste research, which began in 1951 with a study of the fundamentals of the composting process and which continues in 1969 with a research program involving all aspects of solid waste management. This present experience is supplemented by service on various committees, including the National Academy of Sciences-National Research Council-National Academy of Engineering, Committee on Solid Waste Management.

URBAN MAN

Mired in the benthic interface
Where sky meets land and sea
He stands, possessed of affluence,
Amid his own debris.

He smells the fetid waters.
He sees brown atmosphere.
He amplifies the decibels
That smite his fragile ear.

Blind hate degrades his reason.
Welfare breeds on urban blight.
Noonday darkness strangles sunlight.
Neon day pollutes his night.

—*P. H. McGAUHEY*

AMERICAN COMPOSTING CONCEPTS

MARCH 1969

OF THE VARIOUS PROCESSES that have been associated with the disposal of municipal refuse, only deposit on land or under the sea has had the potential to accept all fractions of the solid wastes generated by a modern urban society. All other processes in themselves have been only capable of dealing with some particular fraction in some selective way. In more specific terms, it might be said that we may, with current technology, put essentially all urban-generated wastes in a landfill, or on the ocean floor, if we wish to develop the necessary techniques. In contrast, composting and incineration are directly concerned with the conversion of the organic component of the overall wastes, although as processes they are in reality but components of some overall management system.

Of the two conversion processes, only composting salvages the organic matter. It is therefore worthy of research consideration, both because of a general feeling of people that organic resources should be conserved and because of the specific requirement of such rationale in the Solid Waste Disposal Act of 1965 that research be directed to recycling or conversion of waste materials. To this end, a major effort in research, development, and demonstration of composting has been undertaken. Composting, however, is but one of the many aspects of solid waste management requiring similar attention. It is appropriate therefore to inquire at this time whether

the results of this program have established the composting process as a viable waste treatment method, demonstrated its unsuitability, or left important aspects unexplored. To approach an answer, it is necessary to consider the historical and technological aspects of composting, as well as the state of the art which has now been achieved or demonstrated, in the light of cultural and social attitudes.

DEVELOPMENT OF THE COMPOSTING PROCESS

Historical Notes

Attempts to systematize the compost heap by which individual farmers and gardeners have for centuries reclaimed organic matter for return to the soil began in the 1920's, when Sir Albert Howard developed his Indore Process in India and Beccari patented his process in Italy. The Indore Process, however, was labor intensive and required a long period of anaerobic degradation in soil pits. Beccari likewise employed an anaerobic process, although in concrete cells.

The Indore and Beccari processes were readily adaptable to mechanized methods, but for several reasons were not attractive to U.S. cities. The time factor involved was unsuited to American cultural patterns; the objective was foreign to the American heritage of wastefulness and unrelated to any recognized compelling need of Americans; and the process involved land areas not suited to our urban centers nor to the volume and variety of our wastes. Furthermore, anaerobic composting accomplished nothing that a good sanitary landfill might not do in time with less cost and trouble, particularly when no demand for the final product was evident, as was the case in India.

Modern composting had its beginning in the 1930's when attempts were made to speed up the process by aerobic decomposition, and to mechanizing it as well. The Vuilafvoer Maatschappij (VAM) began operations in Holland, the Dano process appeared in Denmark, and Eweson patented a process in the United States. In 1949 the Frazer Process was developed in the United States.

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By about 1950, composting began to be considered as a possible partial answer to municipal solid waste problems for a variety of reasons. First, the wartime growth of small towns into fair-sized cities overwhelmed their primitive systems of open dumps, overran and obliterated the hog farm, and introduced the air pollution factor into environmental considerations. Next, a growing affluence multiplied the volume of urban-generated wastes and so compounded the problem of disposal. Finally, opportunistic entrepreneurs, dedicated conservationists, and food faddists came together in a critical mass. The first group sought to sell to hard-pressed public works officials untried and unevaluated composting processes, generally conceived by caprice or in well-meaning naiveté. The second group comprised citizens of all classes who had, and continue to have, the uneasy feeling that the Nation cannot forever go on wasting its resources. The last group, though small in number, were the organic gardeners who, by rational deduction or as "true believers," had come to stress the importance of organic fertilizers as compared to inorganic chemicals in the nutritive value of foods.

In the foregoing situation, despite claims and process patents, no one in fact knew the scientific rudiments or the engineering parameters of aerobic composting. One of the most highly advertised and most insistent tenets of the entrepreneur was that a special inoculum, which good fortune and scientific dedication had revealed to him alone, was the key to quick and successful composting of municipal refuse. In some cases, both a special inoculum and unique cells and equipment were required to carry out the secret proprietary process. In one instance, carbon dioxide generated at the bottom of the composting mass was presumed to acquire unusual characteristics and so rose through the composting mass, shedding the blessings and magic on which the process depended. Chemical additives, pH control, forced aeration, and numerous other features all had supporters when composting was proposed.

Under pressure from advocates of various systems, and confronted with newspaper articles both heralding composting as the answer to municipal refuse problems and berating the public official for his shortcomings, officials turned to the engineering profession for the answer. In a few cases, they turned also to various arrangements to set up composting plants. It was at once evident that the engineer, whether he be skeptical or gullible, could not provide the required technical and economic answer. The limited knowledge of biology, which at that time characterized the public works engineer, led many to accept the concept that special inoculums and a great deal of recycling and reseeding were necessary. The latter concept was supported by experience in sewage sludge digestion, which had been found to benefit from continuous mixing. An equally unsatisfactory answer could be obtained from microbiologists, because at that time the profession of biology had not yet turned its attention to ways in which engineered systems might put biological knowledge to work for overall environmental goals.

Research was needed, therefore, in order to determine the entire basis of the composting process. This included: (1) determination of the scientific fundamentals of aerobic degradation of heterogeneous organic matter; (2) determination of the environmental conditions to be maintained to maximize the rate of aerobic composting and of methods for controlling the conditions; (3) evaluation of the effects of inoculums, recycling, and reseeding on the composting process; (4) determination of the materials handling necessary for a successful composting process (preprocessing, etc.); (5) determination of the fate of pathogens, fly larvae, and other disease vectors in composting; (6) evaluation of the fertilizing and soil-conditioning

values of compost; (7) determination of the cost of producing compost; (8) evaluation of the utility of the finished compost.

Early Research Findings

Research programs begun in 1950 by the State of California, the University of California, the U.S. Public Health Service, and others had established by 1955 a number of findings that are particularly important now to the evaluation of the research program to which this review is addressed.[1-4] Among the most important accomplishments of this program were: (1) The fundamentals of aerobic composting and the necessary operating parameters were established for municipal refuse. (2) Windrow composting in the open was shown to be a simple procedure. (3) Inoculums were shown to be unnecessary and those offered for sale to be worthless. (4) Recycling for reseeding purposes was shown to be of little, if any, value to the process and the reasons established in terms of sequence of microorganisms. (5) Simple turning was shown to be an effective way of maintaining needed aeration. (6) Aerobic composting was shown to be a semi-aerobic process requiring far less aeration than the term implied. (7) Forced aeration was shown to be technologically difficult to accomplish and the least likely way to aerate a composting mass. (8) A composting mass permitted to become anaerobic was found to resume aerobic decomposition if aerated again by turning. (9) The process was found to continue to completion without further aeration after a relatively short period of composting under aerobic conditions. (10) The process was found to be applicable to animal manures, cannery wastes, and other organic refuse. (11) Fly control and destruction of disease vectors was found to occur in the process. (12) Finished compost was found to be a lowgrade fertilizer, more valuable for its soil-conditioning and

moisture-retaining properties than for its content of nitrogen and phosphorus. (13) The feasibility of reducing the area of land required for landfill by composting and compacting the organic fraction of municipal refuse was demonstrated and evaluated. (14) The cost of composting was variously postulated, but it was evident that the process was not destined to be a source of income to cities which would pay much of the cost of refuse disposal. (15) Serious doubts were cast upon the marketability of any large amount of compost.

More Recent Findings

The research and development activity of the early 1950's established the environmental conditions that any composting procedure would need to maintain in order to exploit the process successfully. These conditions established the objectives of the design of any technological process. Early attempts to commercialize the process that paralleled the early research gave some notice as to what technological difficulties needed to be resolved. For example, economical segregation of refuse was found to be difficult; excessive wear and failure of shredding equipment was experienced; and pelletizing of compost was found to be exceedingly hard on equipment. Compounding technological problems was the continued insistence of some proprietary equipment owners that elaborate procedures (pre-dating the early research) were essential to the composting process, rather than simply features of their own particular devices.

Constraints upon the compost plant designer were among the first findings of research following the original fundamental studies.[1] Among the most significant of the findings were the following: (1) The open windrow method of composting requires land area not readily available in urban areas, together with a degree of

"housekeeping" that traditional practice has not led the public to expect. (2) The city cannot, itself, with its own funds, undertake to develop a technologically and economically untried process, nor can it enter into a marketing business under its charter. (3) Public officials and the public itself prefer a housed, factory-type composter that receives refuse at one end and discharges compost ready for market at the other. (4) The problems of siting of a compost plant within a community are just as difficult as those of an incinerator or transfer station. (5) The idea that compost must be produced for sale at a profit is exceedingly persistent. (6) The idea that composting will solve all municipal solid waste problems while conserving a national resource and yielding a neat profit to the city continues to be rediscovered and projected at regular intervals not exceeding one lunar month.

More recent findings of private enterprise and of demonstration grants by the Bureau of Solid Waste Management have established several additional facts.[5-7] These follow: (7) Composting in a full-scale mechanized plant is technologically feasible, and involves mechanical problems which can be surmounted as operational experience accumulates. (8) The fundamental requirements of composting can be met by straightforward design which eliminates a considerable amount of the initial and operating costs of the older proprietary systems. (9) The economics of composting can not be fully established without first solving the problem of what to do with the compost. (10) In some cases, at least (e.g., Fresno), the most economical system of regional solid waste management involves composting of organic wastes prior to landfill.

Some Current Concepts

Before turning to a specific evaluation of the current status of composting and the role of the Bureau of Solid Waste Management

in the future of the process, additional background may be found in examining some current concepts of composting.

The first, and most persistent, is the concept of composting as a reclamation of the organic fraction of solid wastes for immediate return to the land via sale to agriculturists and related smaller users of fertilizers.

The second concept, originally demonstrated by the Public Health Service at Phoenix, Arizona, and recently verified in studies at Fresno, California, under PHS sponsorship, is that composting may materially reduce the volume of solids substantially and so conserve available landfill sites, reduce the insult to the land environment, and shorten the period between completion of a landfill and subsequent beneficial use of the filled area.

A third concept currently advocated by the author and others, is that in effectively reclaiming the resource values of solid wastes in a production-composting-use cycle, a time period may be necessary at either the production-composting or the composting-use phase of the cycle.

Implications of each of these three concepts have been examined in the following discussion.

EVALUATION OF THE COMPOSTING PROCESS

Value of Compost as a Soil Conditioner

THE VALUE OF COMPOST as a soil conditioner may be considered from three viewpoints: (1) As a fertilizer in comparison with chemicals. (2) As a source of income to defray some of the cost of solid waste management. (3) As a resource to be conserved.

Compost in the Soil. There is ample evidence upon which to evaluate compost as a soil conditioner in relation to commercial chemicals. It generally contains less than 1 percent of nitrogen, 0.05 to 0.2 percent phosphate, plus 0.2 to 0.3 percent potassium. Thus, unless fortified with chemicals, compost may not be sold in the United States as a fertilizer. Agriculturists point out that the amount of nitrogen and phosphorus present in compost can be bought more cheaply in commercial fertilizer. Furthermore, chemicals are much more readily and cheaply applied to the land, therefore, the value of compost on the soil depends largely on its characteristics as a humus and, perhaps, on its content of trace elements.

The ability of humus to improve the physical characteristics of soil, to hold moisture, and to comprise a biological system from which nitrogen is released over a period of time, is well established and is one of its major virtues. Numerous experiments have shown that lawn areas treated with compost show superior growth when compared with adjacent areas treated only with fertilizers. In commercial agriculture, this value is not apparent. The use of liquid ammonia as a fertilizer offsets the nitrogen-holding virtue of compost. In humid regions, soils often have a good organic content and receive adequate rainfall; and in irrigated areas water is applied as needed. Experiments over a 100-year period in Illinois and in

England show that root structure alone is sufficient to provide the organic content needed in soil, even though the plants are harvested and removed from the land. Even in the semi-arid Southwest, where temperatures are conducive to year-round activity of soil micro-organisms and where soils might be expected to need added humus, there has been found as yet no compelling need for adding humus to maintain productivity.

Thus, the value of compost in soils in the short run is effectually depreciated unless trace elements can be shown to be the critical consideration. Evaluations of this sort are more appropriate to the Agricultural Experiment Stations than to the Public Health Service. However, the case for compost on the basis of trace elements rests largely with the organic gardening enthusiasts, who are few in number and might be written off as "faddists," even though time might prove them to be prophets. Furthermore, the trace-element argument for composting is weakened by the rationale that the crop residues available for production of compost are grown with commercial fertilizer, garbage is increasingly ground to the sewer, the resulting sludge disposed of by incineration, and that municipal refuse is increasingly characterized by carbonaceous organic matter and synthetics. The conclusion from this line of reasoning is that compost is derived from materials with no source of trace elements but the soil; in the absence of evidence that the soil bank is about to go broke, the easy thing to do is to forget the trace element question.

The foregoing considerations mean that compost in the soil must be evaluated from a long-term resource viewpoint.

Compost in Resource Conservation. As solid waste management takes on regional aspects, more than household refuse is involved in organic refuse. Tree and grass trimmings, animal manures, crop residues, and demolition debris are added to the total degradable mass. Thus, both composition and amount of compost which might be produced is changed. If resource conservation and recycling of

resource materials continue to develop as an aspect of solid waste management, however, much of the paper and other wood products may be removed from the waste stream ahead of the composting process. The concept of composting then becomes that of salvage of remaining organic resources value for the land in maintaining productivity. The idea that such resource conservation will be necessary in America in the forseeable future is widely accepted by the public on a rational basis. Thus there is public support for composting as a conservation measure and justification for research and development of the process by public agencies if such research and development activity is needed. As previously noted, the Solid Waste Disposal Act requires research of this nature, leaving the decision as to need for research on any particular process to the proper administrative agency. There seems little reason to doubt that composting is one way to conserve and recycle resource values existing in solid wastes.

The question, then, is how and when these salvaged resources are to be put to use.

Compost as a Paying Process. Because composting was first proposed as a process for solving the solid waste management problem, it was natural that the first concept should be that the soil conditioner and resource conservation merits acclaimed by its adherents should be made to pay the increase in cost over the primitive disposal methods that had created the waste management problem in the first place. Thus, the first of the three concepts of composting (*See* section on Some Current Concepts) come into being, i.e., that compost should be produced and sold to the user on a continuous basis similar to that of the fertilizer industry. This concept was supported by experience abroad, particularly in Holland, Germany, and Switzerland, where compost has for many years been disposed of in agriculture.

This over-optimistic concept proved so attractive that 15 years of frustration and failure in every commercial attempt at composting

during that period has not erased it completely. In evaluating the research and development program of the Bureau of Solid Waste Management (See section on Evaluation of Research and Development Needs), it is necessary, first, to explore the reasons for failure of commercial composting in the United States.

To begin with, the analogy between European and United States conditions was invalid. Compost in Europe was, indeed, being sold, but to the specialty farmer who operated small holdings with a great deal of hand labor. That this type of farming comprised much of European agriculture and very little of U.S. agriculture was overlooked. The truth was that there was a similar, although vastly smaller, market in the United States in the nursery business, in home gardening, and in other special cases. This market, however, was already partially saturated by steer manure and by small-scale composting production by the users themselves. In California, for example, it was estimated that the marketable steer manure is equivalent to two bags per year for every member of the States's population, hence the competition in the soil conditioner market is not encouraging.

From early attempts to commercialize composting in the 1950's and from estimates of the volume of compost that might come from U.S. cities, it was soon evident that if compost was to be marketed in this nation it would have to be sold to large-scale agriculture, except for a few local situations where the specialty market was particularly favorable.

The proposition that compost can be sold to large-scale agriculture has proved invalid also for a number of reasons: (1) In the irrigated West, the application of fertilizer by airplane, or by dissolution in irrigation water, is an established and economical practice. (2) The use of liquid ammonia has proved both economical and technologically simple. (3) Agriculturists are sufficiently satisfied with present practice and commercial fertilizers that disposal of even animal manures in the country is an agricultural

waste problem analagous to the municipal waste problem of the urban center. (4) The mechanics of applying compost to the land are a nuisance. Heavy equipment moving over wet soil is detrimental to agriculture. Compost deposited on snow may wash away to lakes and streams causing problems of pollution. This run-off problem has not yet been resolved with respect to animal manures and agricultural residues. (5) Usually, large-scale agriculture is distant from significant sources of compost, hence transport further complicates the economics of composting.

Experience of the last 15 years makes it amply evident that the U.S. farmer is not currently interested in compost. Recent evidence from abroad is that the European farmer is likewise becoming disinterested wherever commercial fertilizer is available, except for certain small-scale intensive specialty enterprises.

Conclusion. In view of the foregoing situation, the author has reached the following conclusions relative to the value of compost as a soil conditioner: (1) Compost has important value as a soil conditioner beyond its modest contribution of major fertilizer elements. (2) Composting is a process capable of salvaging and recycling inorganic and organic resources in solid wastes. (3) The soil conditioning and resource values of compost are far too small to make compost attractive to U.S. agriculture at this time. (4) Except for local situations where sale of compost for special private or public purposes is favorable, commercial composting for immediate use as a soil conditioner is not economically feasible.

These conclusions lead to the greater, and perhaps forlorn, conclusion that *the value of compost for immediate use as a soil conditioner is essentially zero.* How this conclusion may be modified in the future is considered in the following section of the report.

Composting for Landfill Disposal

From the preceding sections, it may be concluded that although composting for immediate sale to agriculture is not presently

hopeful, the process has potential as one component of an overall solid waste management system. Specifically, benefits from composting for landfilling may lend economic justification to the process. Here there may be two different objectives. Under the first, the biochemical stability, smaller volume, and compressibility of compost results in savings of land area, or in accelerated use of the filled area, which offset processing costs. The filled area, however, is of the nature of reclaimed land rather than a stockpile of reclaimed organic resources that might be mined in the future.

The second objective is also related to land-use economics, but requires a different land-use plan, in which the compost would be considered as in storage until such time as its value as a soil conditioner might justify removing it from storage and to apply it to agricultural land. Here limited and valuable land space might justify composting, but use of the filled area should not be allowed to involve activities that through investment or presumption become vested interests capable of defeating the long-range objectives of resource stockpiling.

Both of these two objectives involve economic determinations pertinent to a local situation rather than to the national situation. One element of the system, however—the nature and cost of a composting plant of specified capacity—is subject to resolution by the research and development efforts of industry and the Federal government. With the cost of processing available, or subject to known parameters, the economics of producing compost for any local project is then subject to well-established engineering methods.

In the case of resource stockpiling as an objective to be achieved by the economic savings from reduced landfill area, the problem requires a careful analysis of alternatives, not all of which are easily evaluated in dollars. The question that the author is inclined to ask (*See* section on Some Current Concepts) is: Why compost at the "production" bridge rather than at the "use" bridge of the resource stockpiling system? The answer depends upon many local factors,

but it seems increasingly evident that in many cases long-distance transport to fill sites is inevitable. Shipping charges and nuisance problems might be reduced by composting refuse in the waste-generation area. On the other hand, when land is valuable enough to require export of waste, the normal difficulties of siting refuse processing installations makes composting prior to transport an unlikely solution. Once the material has reached the fill site, there is no justification for the expense of composting, since space is not critical, and eventual demand for the stockpiled resource is vague as to both time and scale.

The advantages of stockpiling the unsegregated refuse in a landfill are self-evident. Anaerobic composting of the organic matter will begin the process, and it can quickly be finished aerobically at the time of demand. In addition, the accumulated pile of refuse becomes, with time, of such magnitude that separation of the resource values, when needed, can be accomplished economically with industrial-scale equipment.

Cost and Optimum Size of Plants

Questions as to the cost and optimum size of composting plants have largely been predicated on the assumption that compost is to be marketed, and hence that the system should be scaled to yield the most favorable economic picture. If, as the author herein contends, sale of compost is not a realistic objective except in individual situations, generally not involving large-scale agriculture, the whole question becomes academic. The scale of the composting plant is governed either by the volume of wastes available for processing, or by the market which will absorb the product. The cost of composting then depends on a scale determined by considerations other than economic optimization. It also depends upon the method of composting to be used.

Composting has been accomplished by three basic approaches: (1) windrows, in the open or under shed cover; (2) completely

mechanized industrial plants; (3) mixing with soil surface and finished compost.

The first of these methods requires considerable land area, plus a limited amount of preprocessing and materials handling equipment and housekeeping procedures.

The second requires a complex mechanical system, often with dust, odor, noise, and vector control.

The third proceeds with essentially only minimal agricultural-type equipment on appreciable land area.

In the cultural climate of the United States and in light of current environmental goals, it seems prudent to assume that the mechanized system will prevail. Certainly, it is the only one of the three that might require research and development expenditures. *The question for further consideration (See section on Evaluation of Research and Development Needs) then becomes: whether such development has already been accomplished to a degree justified by the prospects for utilizing the composting process in solid waste management.*

If the question of cost and optimum size of plant is posed in the context of processing refuse for landfill efficiency, the answer must again be sought by evaluating a known process against the local waste volume and land value considerations.

It is inconceivable to the author that composting will be applied to the processing of organic wastes as a matter of national policy of resource conservation by stockpiling, when both logic and economics suggest that the same policy might be implemented by stockpiling the raw refuse and deferring processing until the indefinite future. Thus, optimization of plant size as a factor worthy of research and development seems purely academic, and the problem again resolves to one of having technology sufficiently developed to meet the needs of today.

Moreover, the manufacturers of existing compost systems already know the optimum scale for their respective plants, and at least one

has published a brochure indicating 200 tons per day as the "breakpoint."[8]

Public versus Private Operation of Plants

As noted in the first section of this review, the original concept of early entrepreneurs was that the public should build and operate composting plants. Aside from the obvious motives of the seller, there was the real question of ownership and the title to the raw material to be processed. Because only municipal refuse was involved, the public was the obvious owner of the raw material. Inherent conservatism of any public works system and the charter limitations on mercantile business by cities suggested that the logical operator of the compost plant should be private industry. Industry, however, had the same technological handicap as the city, plus the problem of control of its raw material. To acquire rights to refuse on a long-term basis was financially too risky for industry. To subsidize industry on a long-term basis was politically risky to the city should the venture result in a profit to the processor.[8] To top it all, the concept that compost must be sold, and stockpiled for seasonal sale as well, could not be documented as valid.

It required only a limited experience with attempts at commercial composting before the question split into two questions. (1) Why compost at all? (2) Should the public or private industry take on the task of converting a low-value material that no one wants, into a low-value resource material that no one wants?

The first question has been answered in preceding sections in relation to composting for landfill and to overall management systems. The second is highly dependent upon other questions which are currently being pondered. To the author, it seems that if the public utility concept suggested by the NAS-NRC-NAE task committee[8] should become the pattern of regional solid waste management, such a public or semi-public agency should operate the

composting plant. On the other hand, if composting is to be an adjunct to landfilling, it might best be turned over to private industry as an adjunct to salvage of other resource materials in urban wastes. This does not imply that public agencies cannot perform the task, but rather that to compound further the systems that a city must operate simultaneously does not, to the author, seem advisable.

If the time comes when resource values are to be extracted from old and extensive landfills, particularly those serving regional needs, private industry is the logical agency to do the job.

Evaluation of Research and Development Needs

In evaluating past research on composting and the composting process itself, the basic question raised by the considerations cited is whether composting is now sufficiently developed to meet the present needs for, and foreseeable potential of, the process. In answer, it is the author's judgment that: (1) Various current research projects dealing with composting and supported by the Bureau of Solid Waste Management are patently redundant. Specifically, several researchers have set out to determine the basic fundamentals of composting established by similar projects some 15 years ago. In addition, attempts to accelerate composting by blowing air through a compacted mass are being financed despite the history of exploration of the principles, the futility, and even the absurdity of the notion dating back to the 1930's in Europe and to the 1940's in the United States. (2) The principles of composting that engineered systems must be designed to exploit are well established as a result of past efforts of the Communicable Disease Center of the Public Health Service, and, subsequently, the Bureau of Solid Waste Management.[1,2,7,9,10] There is, therefore, little need for research on the principles of composting, as distinct from other possible systems of biodegradation. (3) Development of mechanized

g is a justifiable investment in order to make available to the information necessary to adapt it to local situations in of the process is worthy of consideration; however, such ld be confined to the exploration of certain units of the ther than to setting up a demonstration of an already n system. (4) Due to private enterprise and to support by u of Solid Waste Management, the composting process is loped to a point where debugging in actual operating can complete the task. (5) The limited feasibility of g as a process for solid waste management at the present is existing technology is adequate to the potential; scale of governed by the limited feasible objectives; hence there is lar purpose in seeking to determine the optimum size of *It seems unlikely that the state of the art of composting factor that limits its use in solid waste management.* The Solid Waste Management has made a major contribution velopment of the art of composting, and further major t in research and development should now be laid aside in ore urgent components of the overall solid waste system.

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